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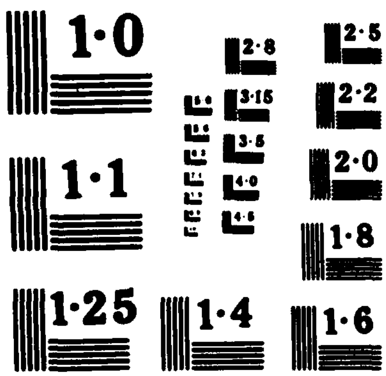
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Quartz Rotary-Table Substrate Holder for Epitaxial Growth Reactor

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This paper concerns the design, fabrication and operation of a rotating quartz substrate holder which was developed for a vapor phase epitaxy (VPE) reactor used to grow the semiconductor InP. This substrate holder is appropriate for exploratory laboratory use and is not readily adaptable for manufacturing applications. This InP epitaxial reactor is arranged so that the vapor species flows parallel to the surface of the substrate during deposition. The crystalline quality of the epilayers grown in a reactor with this geometry has been found to be superior to epilayers grown in a vapor which flows perpendicular to the substrate surface. Under the parallel arrangement, however, distribution of both temperature and vapor species at the substrate can be nonuniform resulting in variations of thickness and composition, especially in large area epilayers. To enhance uniformity of conditions, the holder and therefore the substrate must be rotated during growth.

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QUARTZ ROTARY-TABLE SUBSTRATE HOLDER FOR EPITAXIAL GROWTH REACTOR

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Introduction

This paper concerns the design, fabrication and operation of a rotating quartz substrate holder which was developed for a vapor phase epitaxy (VPE) reactor used to grow the semiconductor InP. This substrate holder is appropriate for exploratory laboratory use and is not readily adaptable for manufacturing applications. This InP epitaxial reactor is arranged so that the vapor species flows parallel to the surface of the substrate during deposition. The crystalline quality of the epilayers grown in a reactor with this geometry has been found to be superior to epilayers grown in a vapor which flows perpendicular to the substrate surface. Under the parallel arrangement, however, distribution of both temperature and vapor species at the substrate can be nonuniform resulting in variations of thickness and composition, especially in large area epilayers. To enhance uniformity of conditions, the holder and therefore the substrate must be rotated during growth.

Figure 1 illustrates the arrangements for obtaining substrate rotation in both the perpendicular (Fig. 1a) and parallel (Fig. 1b) geometries. The origin of motion is the end of the tube exiting the reactor on the left side. It is apparent from Fig. 1a that rotation is easily obtained with the perpendicular geometry. However, rotation is difficult with the parallel geometry (Fig. 1b) where the axis of rotation is perpendicular to the support tube and the manipulation originates from a remote location. The rotator described here provides an effective means of achieving this motion in an exploratory growth system.

Design

Several designs were reviewed before deciding on the one used in this work. The chosen idea was thought to provide the mechanism with the

highest degree of reliable rotation at the possible expense of a more uniform rotation rate for the exploratory growth conditions to be used. In formulating the design, several fundamental factors were considered. First, VPE is generally carried out at temperatures in excess of 650°C, which requires that the reaction tube and substrate holder be fabricated entirely from quartz. Second, the mechanism must be reliable since viewing of the table is impossible when it is in the oven. Finally, a bevel-gear arrangement, if at all possible to produce, would be prohibitively expensive. Also, any gear mechanism would be likely to have jamming problems. This could be due either to vapor condensation or the 48-inch distance between the rotary table and source of motion (Fig. 2).

A device was designed which incorporated a manipulator which could slide and be turned within a fixed support tube. The rotating table is mounted on a spindle which is sealed to the end of the support tube. A labeled photograph of the mechanism is shown in Fig. 3 A series of slots was ground on the underside of the table. The inner manipulator, which extends through both ends of the support tube, can be translated and rotated within the support tube. An engagement rod is sealed to the end of the manipulator so that it may engage and disengage the slots in the table. A sequence of engagement, translation and disengagement serves to rotate the table through a given angle. Thus substrate rotation is achieved by means of a given series of such cycles.

Since these manipulations must be executed from the end of the tube outside the reactor, and rotation cannot be viewed directly, a system of stops must be incorporated. The first stop is the engagement arm contacting the end of the support tube on the return stroke. (Refer to Fig. 3.) The other stops incorporate decal marker lines and serve to define the precise position of the engagement rod relative to the slots, enabling precise rotation cycles to occur. (See Fig. 4.)

Fabrication

The ideal size for the rotary substrate holder was determined to be a 25-mm-diameter bv 3-mm-thick quartz disc. This was adequate to hold the substrate and allowed space for turning the disc in the reactor tube. The first procedure was to concentrically drill the disc with an 1/8-inch diamond-core drill to provide clearance for the 3-mm spindle. The drilled hole also served to center the disc on the indexing table. A 0.090-in.-dia-

meter diamond-core drill was used to grind the slots. An angular spacing of 24° between slots provided an optimum configuration for the chosen slot width (Fig. 5). The slots were then ground in depth increments of 0.010 in. due to the limit of strain on the core drill shank. Six passes were required to obtain the total depth of 0.060 in., which was half the disc thickness. The top of the disc was then counterbored to receive the retaining washer (Fig. 6). This procedure completed the disc. Next the spindle was sealed to the support tube (Fig. 7). The pre-drilled bearing plate was then placed over the spindle and also sealed to the support tube. The disc was then put on the spindle and the retaining washer was set into the counterbore. At this point, a 0.001-inch shim was inserted between the disc and the bearing plate, and the seal was made between the top of the spindle and the retaining washer. With the shim removed, sufficient clearance was provided for smooth and easy rotation.

The engagement rod was then fabricated. A 2-mm-diameter rod size was chosen as having sufficient strength while allowing a compatible fit with the slot size in the base of the disc. The rod was fabricated with the correct radial spacing to provide accurate engagement of slots. This distance between the rod and the center of the table was also critical so that sufficient rotary travel could be realized without exceeding the mechanical limits of the design. The decals were then positioned and baked on, giving orientation information about the engagement rod to the person using the manipulator. After fusing small hooks around the rim of the table and testing the table rotation for reliability, the device was ready to be used in the epitaxial reactor.

Operation

The sequence of operation of the rotary table is illustrated in Fig. 8. First the manipulator is rotated so as to insert the engagement rod into a slot in the bottom of the rotary table. The manipulator is then moved forward to the marker which rotates the table 1/5 turn. The manipulator is next counterrotated, which enables the engagement rod to clear the table as it is pulled back against the stop. This returns the manipulator to the starting position. A sequence every 3 min. results in a rotation rate of 4 revolutions per hour. A cycle can be started in any slot. Although only 5 slots are needed, the extra slots provide optional rotation cycles.

Results

The rotary table substrate holder was operated in an experimental reactor for the growth of InP epilayers where it was necessary to place the substrate parallel to the flow direction of the vapor species (Fig. 9). Substrates were typically 1 sq. in. in area. Prior to using the rotary table, epilayer thickness could vary as much as 25% over the area of a nominally 6-μm-thick layer. Electrical characteristics were found to be nonuniform. As a result of the incorporation of the rotary table, epilayer thicknesses varied less than 10%, and electrical uniformity characteristics were significantly improved.[1]

The design choice proved to be mechanically reliable. The cleaning procedure between runs originally included a lengthy and concentrated HF acid etch. This was detrimental to the spindle and retainer clearances, and the table loosened slightly. The etch time and acid concentration were reduced, and the table continued to work satisfactorily.

Conclusions

In this paper, the design, fabrication and operation of a quartz rotary-table substrate holder for exploratory experimental InP epitaxial growth was described. In addition to the successful operation of the table, a significant factor of this presentation is the demonstration that using readily available resources, somewhat unconventional but adequate methods, and the glassblower's creative potential, most technical challenges can be met.

This work was supported by the Department of the Air Force.

Reference

[1] P. Vohl, F.J.Leonberger and F.J. O'Donnell, "Lateral Epitaxial Growth of InP over PSG Films for Oxide-confined Optical Waveguides," Electronic Materials Conference, Ft. Collins, CO, 1982.

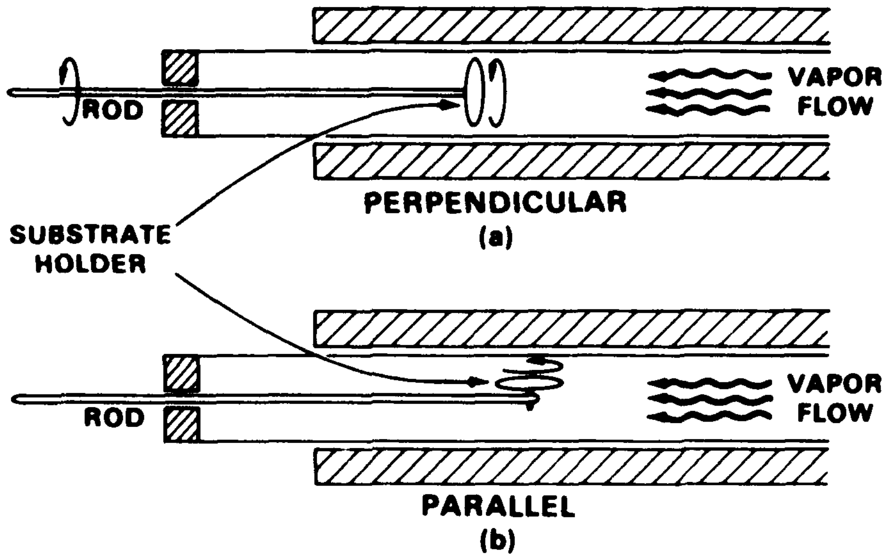

Fig. 1 Representation of Perpendicular and Parallel Vapor Flow in a Vapor Phase Epitaxial Reactor

Fig. 2 Entire Rotary-Table Mechanism Showing 48-inch Length

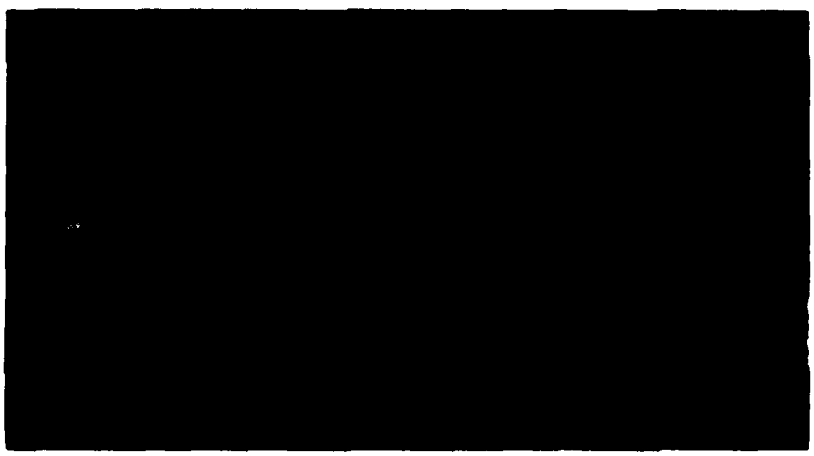

Fig. 3 Quartz Rotary-Table with Major Parts Labeled

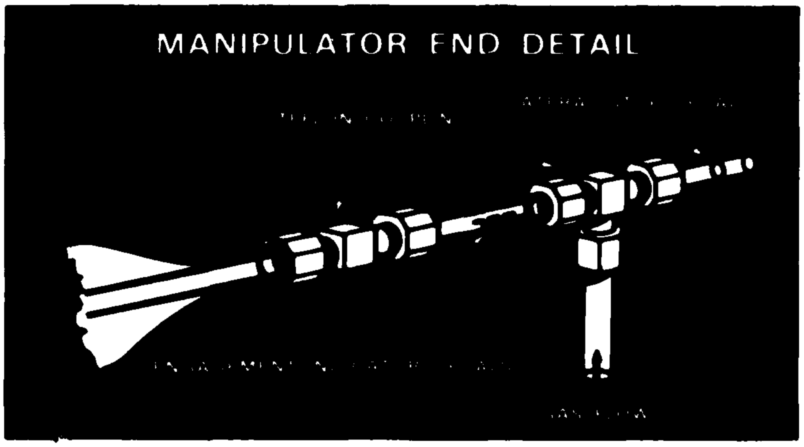

Fig. 4 Manipulator End of Support Tube Showing Decal Markers

Fig. 5 Quartz Disc Being Ground in Milling Machine

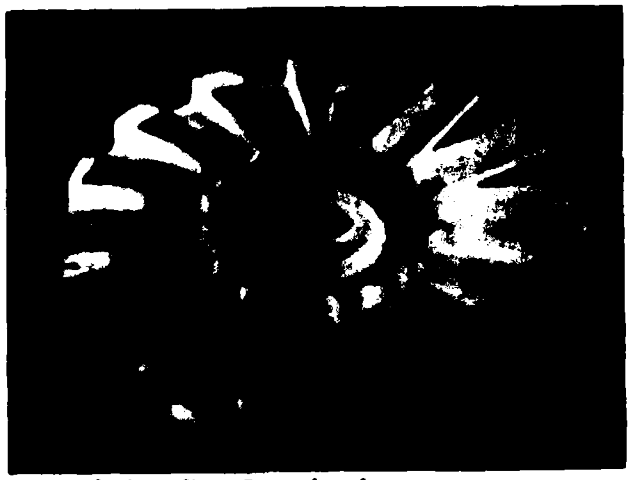

Fig. 6 Disc with Grinding Completed

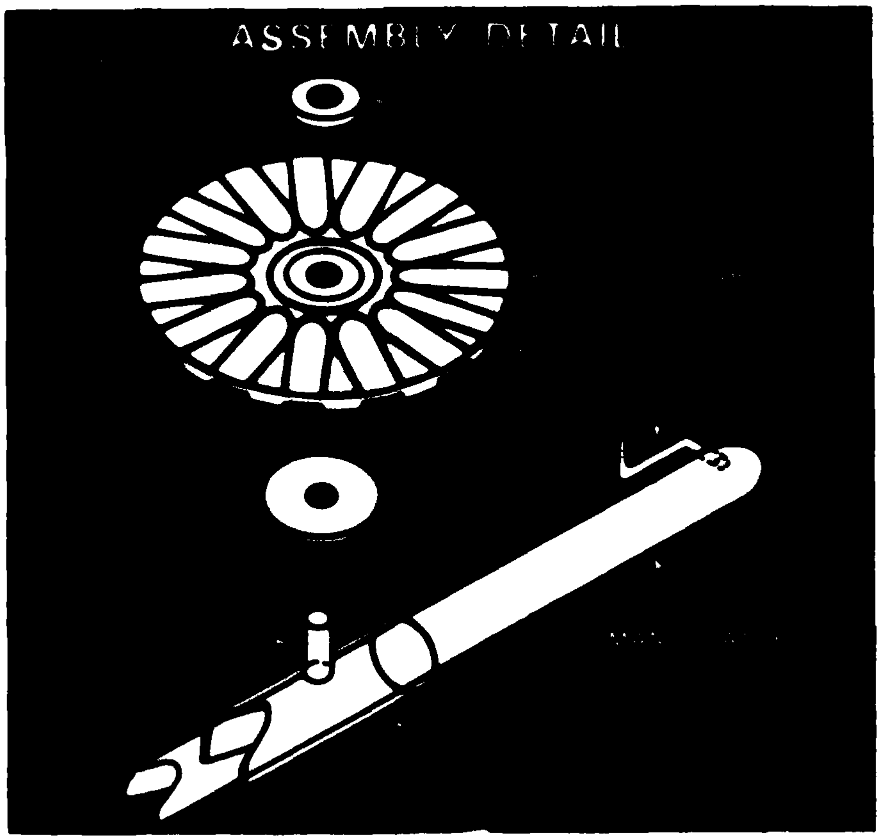

Fig. 7 Blow-up of Table for Describing Fabrication Procedure

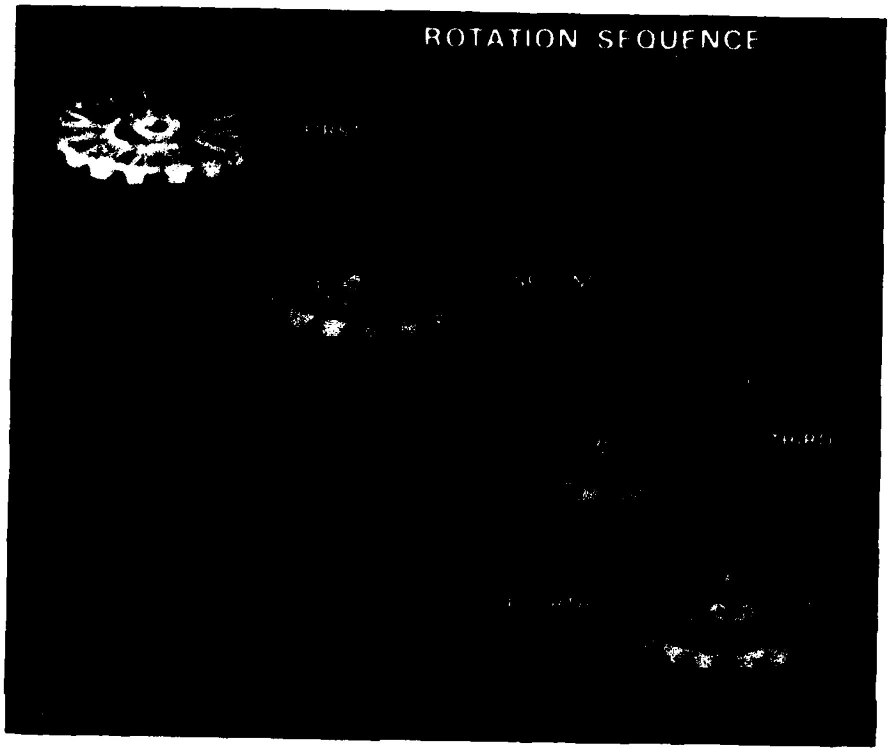

Fig. 8 4-Picture Composite Showing Rotation Sequence

Fig. 9 Rotary-Table Holding Substrate Inside Reaction Tube

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